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FORAGE AND GRAZING MANAGEMENT

Diet Quality and Performance of Heifers in the Subtropics

Mimi J. Williams,* Chadwick C. Chase, Jr., and Andrew C. Hammond

ABSTRACT

The effects of continuous vs. rotational stocking of bahiagrass (*Paspalum notatum* Flugge), previous winter nutritional regimen [corn (*Zea mays* L.) + soybean [*Glycine max* (L.) Merr.] meal (CS) vs. soybean meal (SBM)], and breed [Angus, Hereford, and Senepol (*Bos taurus*) and Brahman (*B. indicus*)] were determined in 1990 to 1992. Forage mass [kg ha⁻¹ dry matter (DM)], forage nutritive value [crude protein (CP) and in vitro organic matter digestibility (IVOMD)], average daily gain (ADG), body weight (BW), body condition score (BCS), and plasma urea N (PUN) and glucose (PGLU) were measured. There was a consistent carryover effect ($P < 0.05$) of winter supplementation for initial BW and BCS, with CS > SBM while for PUN, SBM > CS. Breed affected most animal variables, with the general ranking of Angus \leq Hereford \leq Brahman and Senepol. Forage mass varied from an average of 1000 kg ha⁻¹ in 1990 to 2000 kg ha⁻¹ in 1992 because of rainfall distribution. Grazing treatment did not affect forage DM, CP, or IVOMD, but heifers that were continuously grazed had higher ($P = 0.0001$) PUN levels than heifers that were rotationally grazed. Only during 1990, when dry weather restricted forage growth, did this translate into a trend for improved ADG and final BW. Because grazing management did not affect heifer performance in most years, the effects noted in this study resulted from: (i) the change in forage nutritive value during the grazing season; (ii) the carryover effect of previous winter supplementation; and (iii) breed differences, particularly temperate vs. tropical breeds.

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TO ACHIEVE PRODUCTION EFFICIENCY, most beef replacement heifers are developed on tropical forage-based diets in the Gulf Coast region of the USA. Consequently, grazing management that maximizes per-animal gains from tropical grasses during the growth and development phase of heifers is more important to cow-calf producers in the Gulf Coast region than grazing strategies that maximize gains per unit of land area. Little is known about the effect of the possible interaction of grazing method and environment on heifer growth rate in this region.

Nutritive value of tropical grasses in this environment is highest in the spring but declines rapidly when growth rate accelerates in the summer (Sollenberger et al., 1988; Williams et al., 1991; Williams, 1994; Williams and Hammond, 1999). Environmental factors such as cool temperatures or drought that moderately restrict growth can result in improved nutritive value of grasses (Minson, 1990).

In general, under tropical conditions where animal performance is lower than temperate regions, continuous stocking is favored because, in part, many tropical grasses tolerate this type of grazing management (t'Mannetje, 1978). Rotational stocking can result in improved persistence and more timely utilization of available forage (Matches and Burns, 1995). Greater

Abbreviations: ADG, average daily gain; BCS, body condition score; BW, body weight; CP, crude protein; CS, corn + soybean meal; DM, dry matter; IVOMD, in vitro organic matter digestibility; PGLU, plasma urea glucose; PUN, plasma urea nitrogen; SBM, soybean meal.

herbage mass has often been reported with rotational stocking (Emmick et al., 1990; Maposse et al., 1996), which suggests that at fixed stocking rates, selectivity might be improved. However, with tropical grasses, rotational stocking can be disadvantageous in terms of individual animal gains because of the rapid decline in the overall forage quality of the sward when rotational paddocks are rested (Bransby, 1983; Roquette, 1988).

An important component of beef cattle production efficiency is genotype (breed) \times environment interaction (Butts et al., 1971; Olson et al., 1991). Better understanding of how and why differing breeds function in a given environment is particularly critical for cow-calf producers to make rational decisions when selecting a breed or breeds to compose the base cow herd.

Traditionally, in the subtropical USA, beef cattle producers have relied on some degree of *Bos indicus* influence (Olson et al., 1991), mainly from the American Gray Brahman breed. Market discounts associated with lower carcass quality usually found with Brahman-influenced cattle have led to efforts to identify tropically adapted *B. taurus* breeds such as the Senepol, which may offer tropical adaptation without the consequence of lower carcass quality (Hammond et al., 1996).

The objective of this study was to determine the effect of grazing management (continuous vs. rotational stocking) on the performance [initial and final body weight (BW), body condition score (BCS), average daily gain (ADG), plasma urea N (PUN), and plasma urea glucose (PGLU)] of differing breeds of yearling heifers in the subtropical USA and to determine if there is a carryover effect of low levels of supplements fed during the winter on subsequent summer performance of heifers.

MATERIALS AND METHODS

The study was conducted from 1990 to 1992 at the USDA-ARS Subtropical Agricultural Research Station (STARS), Brooksville, FL (28°37' N, 82°22' W). Monthly average rainfall and temperature from 1990 to 1992 are shown in Fig. 1. Four 16-ha pastures of established 'Pensacola' bahiagrass on an excessively drained Candler fine sand (hyperthermic, uncoated Typic Quartzipsamment) were blocked into two replicates based on previous experience with forage production, and one pasture in each block was subdivided into four 4-ha paddocks. In March of each year, 336 kg ha⁻¹ of 20-5-10 fertilizer was applied. Each year, when sufficient forage growth was available (23 Apr. 1990, 17 Apr. 1991, and 6 May 1992), yearling heifers were either continuously or rotationally stocked on these pastures until the fall when forage mass became limiting or animal performance declined (7 Nov. 1990, 2 Oct. 1991, and 14 Oct. 1992). Heifers on the rotational treatment were moved on a calendar basis every 7 d throughout the grazing season.

The heifers previously had been wintered on either of two supplementation regimens: 2.27 kg d⁻¹ of a 75% cracked corn-25% soybean meal mix (CS) or 0.91 kg d⁻¹ of soybean meal (SBM). In addition to the supplement, the heifers were offered large, round bale bahiagrass hay free-choice on bahiagrass pasture, and hay intake was not recorded. Total supplement requirements for the week were divided between three feedings a week and fed on Monday, Wednesday, and Friday of each week. Each of the supplements (as-fed basis) provided similar amounts of crude protein (CP; 0.40 kg d⁻¹ intake CP);

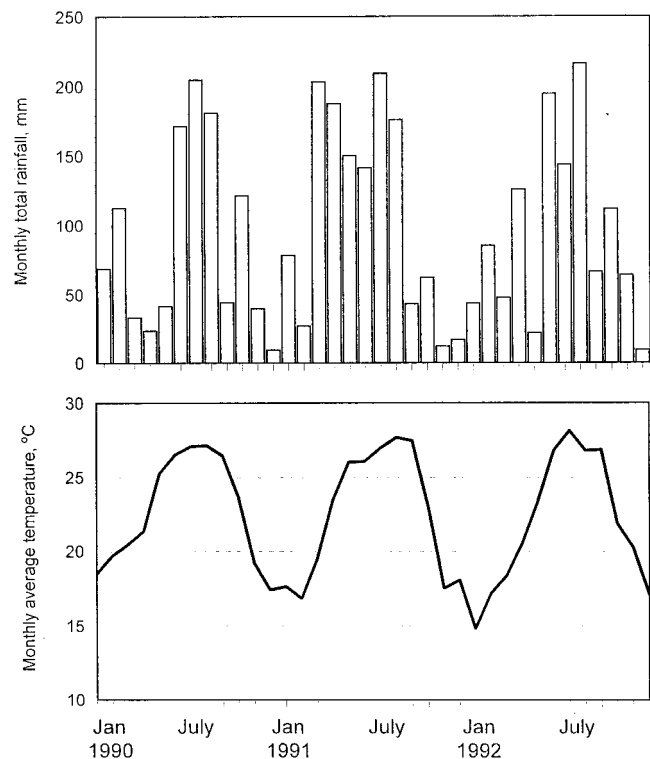


Fig. 1. Monthly rainfall (mm) and average monthly temperature (°C) at the USDA-ARS Subtropical Agricultural Research Station, Brooksville, FL in 1990, 1991, and 1992.

however, the CS supplement provided 2.5 times the amount of total digestible nutrients as the SBM supplement (1.76 vs. 0.68 kg d⁻¹ intake total digestible nutrients, respectively; Natl. Res. Council, 1996). Both supplements contained 150 mg d⁻¹ monensin. Half of the heifers from winter supplementation treatments were allotted to each of the summer grazing management treatments.

Breeds differed over the 3 yr (Table 1) but included Angus and Hereford (temperate *B. taurus*), Brahman (tropical *B. indicus*), and Senepol (tropical *B. taurus*) each year. Although all heifers were used to determine stocking rate, only Angus, Hereford, Brahman, and Senepol were used in the statistical analysis of animal performance variables. Heifers were stratified according to breed, winter treatment, and initial BW and randomly assigned to the summer grazing treatment-replicate combinations. Total number of heifers differed slightly among the 3 yr because of variation in the number of heifer calves born each year, death losses in 1991 due to causes unrelated to grazing management ($n = 8$), and some heifers being removed during the grazing season in 1991 and 1992 ($n = 6$ each year) for an additional study (Simpson et al., 1998). Therefore,

Table 1. Breed and number of heifers at the start of the summer grazing treatments in 1990, 1991 and 1992.

Breed	1990	1991	1992
		no.	
Angus	44	36	43
Hereford (H)	24	35	14
Brahman	44	36	15
Senepol (S)	33	26	17
S \times H		9	6
H \times S		10	6
Nellore			13
Romosinuano			23
Total	145	152	137

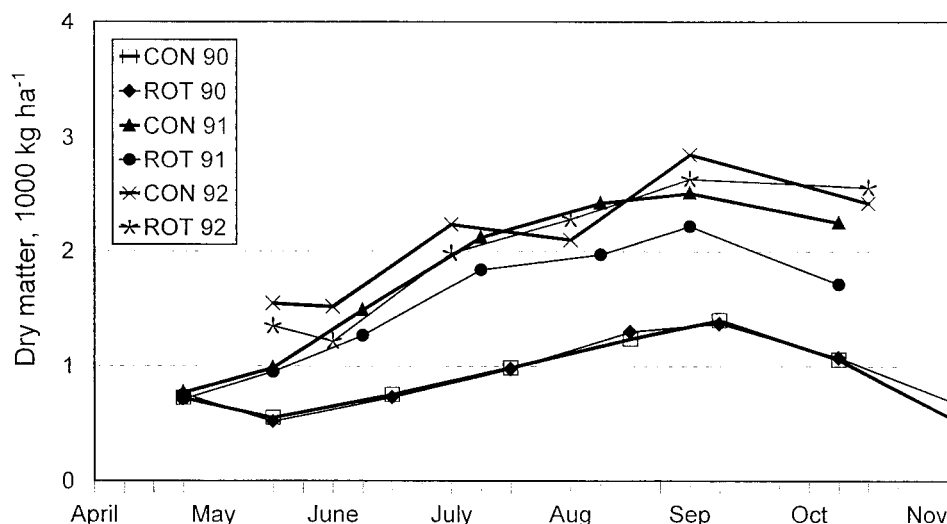


Fig. 2. Forage mass availability on continuously (CON) and rotationally (ROT) grazed bahiagrass pastures in 1990, 1991, and 1992.

stocking rate for the summer grazing season ranged from 2.1 to 2.4 head ha^{-1} over the 3 yr but was the same for both grazing treatments during any given year.

Full weights were measured (between 0900 and 1200 h) at the start (initial BW) and end (final BW) of the grazing season and at 28-d intervals during the grazing season. At the same times, BCS (1–17 scale: 1 = fully emaciated and 17 = obese) was recorded. The BCS system used included three relative degrees of emaciation (BCS = 4, 5, and 6), 2.5 mm of estimated fat over the ribeye (BCS = 7), and one-unit increase for each 1.3-mm increase in estimated fat over the ribeye (BCS = 8, 9, and 10). Average daily gains were calculated for each 28-d interval. Plasma concentrations of urea N and PGLU were determined from blood samples [jugular veinipuncture, stored on ice until plasma separated in refrigerated centrifuge and stored frozen [-18°C] until PUN was measured] from a subset of heifers ($n \leq 5$ head/breed per treatment-replicate combination) collected at the start of the grazing season and every 56 d during the grazing season. Initial PUN samples were collected from 24 to 72 h after last supplementation feeding, depending on year. Concentration of PUN was determined by a modification of the automated diacetyl-monoxime method of Marsh et al. (1965; Ind. Method 339-01, Technicon Ind. Syst., Tarrytown, NY). Glucose concentration was determined by an automated method (Ind. Method 339-19, Technicon Ind. Syst., Tarrytown, NY) based on the glucose oxidase procedure described by Gochman and Schmitz (1972).

Forage mass was determined on approximately 28-d intervals from the start of the grazing season until the heifers were removed using a double sampling procedure (Ahmed et al., 1983) with a 0.25-m^2 disk meter dropped from an 85-cm height (t'Mannetje, 1978). Approximately 80 compressed-height measurements were taken per pasture (in the rotational grazing treatment, 20 samples per paddock were collected), eight of which were clipped to a 0.5-cm stubble height and oven-dried (60°C) for dry matter (DM) determination. A single regression equation for estimating forage mass (Ahmed et al., 1983) was generated for the 3 yr of disk meter samples (forage mass = $-1.899 + 6.8345 \times \text{height}$; $r^2 = 0.65$). After weighing, clipped samples were combined on a per-pasture basis and ground through a 1-mm screen for determination of CP (Gallaher et al., 1975) and in vitro organic matter digestibility (IVOMD; Moore and Mott, 1974) at the University of Florida Forage Evaluation Support Laboratory, Gainesville.

Because of differences in the length of the grazing season

and different sampling dates, data were analyzed separately by year by repeated-measures analysis using the PROC MIXED procedure of SAS (SAS Inst., 1996), with a factorial arrangement of summer treatment (continuous vs. rotational), winter treatment (CS vs. SBM), and breed tested, with replicate (summer treatment \times winter treatment \times breed) for the error term. Effect of sample date and the interaction of date with summer treatment, winter treatment, and breed were tested with the residual error term.

RESULTS

Similar to previous studies with fixed stocking rates on bahiagrass at this location (Williams and Hammond, 1999), forage mass did not differ between continuous or rotational grazing treatments in any year (Fig. 2). Forage mass varied across years, averaging approximately 1000, 1600, and 2000 kg ha^{-1} in 1990, 1991, and 1992, respectively. In 1990, forage mass declined to about 500 kg ha^{-1} during the April–May period because of drought. Average forage nutritive value was not affected by grazing treatment in any year although differences in CP (Fig. 3) and IVOMD (Fig. 4) were observed across the years and among sampling dates within years. Crude protein and IVOMD were generally higher in the spring and fall months in 1990, the year when grass growth was restricted the most, than in 1991 and 1992.

Although whole plant samples did not reflect any differences in standing crop CP and IVOMD, within years there was a summer treatment \times sample date interaction ($P < 0.001$) for PUN, which usually was higher for heifers on continuously grazed pastures than for heifers on rotationally grazed pastures (Fig. 5). Additionally, there were winter treatment \times sample date and breed \times sample date interactions ($P < 0.01$) each year for PUN. Because all of the heifers had been on bahiagrass pastures during the previous supplementation period, the winter treatment \times sample date interaction found for PUN levels at the start of the summer grazing phase reflected a short-term carryover effect of previous winter supplementation not a seasonal difference due to bahiagrass quality. Heifers that received

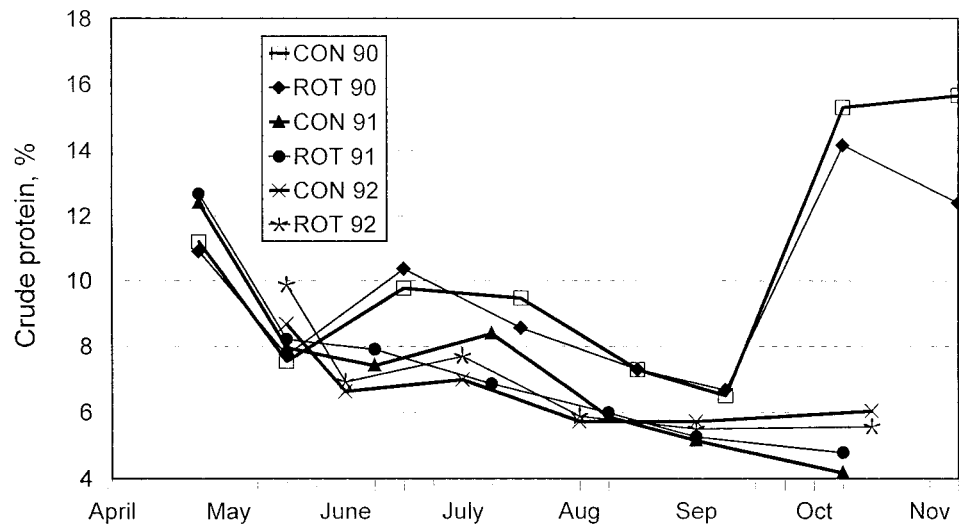


Fig. 3. Crude protein (CP) content of continuously (CON) and rotationally (ROT) grazed bahiagrass pastures in 1990, 1991, and 1992.

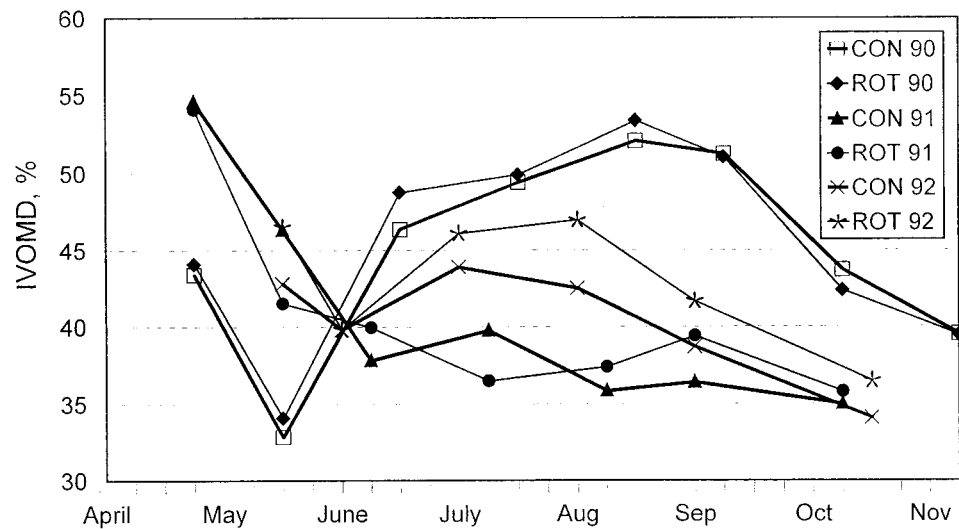


Fig. 4. In vitro organic matter digestibility (IVOMD) of continuously (CON) and rotationally (ROT) grazed bahiagrass pastures in 1990, 1991, and 1992.

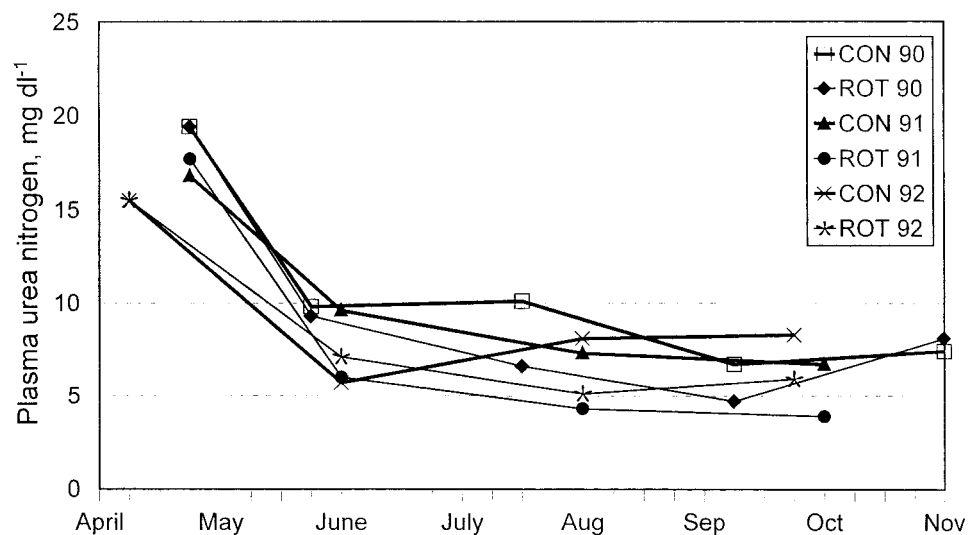


Fig. 5. Plasma urea nitrogen (PUN) concentration of heifers continuously (CON) or rotationally (ROT) grazing bahiagrass pastures in 1990, 1991, and 1992.

the SBM supplement had initial PUN values that were two to eight units higher (19.5 ± 0.40 vs. 15.0 ± 0.42 mg dL⁻¹, 3-yr average of initial sample date, respectively) at the first summer sampling date than those receiving the CS supplement. At all subsequent sampling dates during the summer grazing period, there was no effect of winter treatment on PUN. Breed \times sample date interactions occurred each year but were not consistent; however, breed effects were consistent ($P < 0.01$). Plasma urea N levels of the tropically adapted Senepol and Brahman heifers were similar to or up to two units higher than the temperate Angus and Hereford heifers (3-yr average of 8.4 ± 0.53 , 9.3 ± 0.40 , 9.4 ± 0.41 , and 10.3 ± 0.37 mg dL⁻¹ for Angus, Hereford, Brahman, and Senepol, respectively).

In contrast, PGLU was not affected by either winter or summer treatments but was affected by breed ($P < 0.001$) and sampling date ($P < 0.001$). Like PUN, PGLU levels were highest at the first sampling date during the summer grazing period in 1991 and 1992 (79.5 ± 0.77 , 68.7 ± 0.76 , 70.7 ± 0.77 , and 68.0 ± 0.80 mg dL⁻¹ in 1991 and 87.9 ± 0.85 , 76.9 ± 0.86 , 79.5 ± 0.88 , and 79.7 ± 0.89 mg dL⁻¹ in 1992 for April, June, August, and October, respectively). But in 1990, PGLU levels were highest during the middle of the grazing season (65.4 ± 0.90 , 53.6 ± 0.90 , 75.1 ± 0.90 , 73.5 ± 0.90 , and 68.5 ± 0.93 mg dL⁻¹ in April, May, July, September, and October, respectively). This probably resulted from limited forage mass during April and May that year. Breed effects for PGLU were similar to those found for PUN, with higher PGLU levels for the tropically adapted breeds, particularly the Brahman, compared with the temperate breeds (3-yr average of 70.9 ± 1.22 , 69.3 ± 1.46 , 78.1 ± 1.52 , and 73.9 ± 1.33 mg dL⁻¹ for Angus, Hereford, Brahman, and Senepol, respectively).

Although PUN data indicated that the heifers on the continuous grazing treatment were able to select a higher quality diet, the differences in diet quality only showed a trend ($P = 0.08$) for grazing management differences in ADG in 1990 when continuous $>$ rotational (0.30 ± 0.02 vs. 0.25 ± 0.02 kg d⁻¹, respectively). There was a summer treatment \times sample date interaction ($P < 0.001$) each year, which in most cases, may have reflected normal variation in gut fill (Fig. 6a, 6b, and 6c). On both treatments, during the May grazing period in 1990, heifers failed to make any gains, further indicating that forage DM availability was limiting during that time. Breed affected ADG ($P < 0.01$) during all 3 yr, with ADG of Brahman being consistently highest (3-yr average of 0.25 ± 0.019 , 0.31 ± 0.031 , 0.39 ± 0.023 , and 0.31 ± 0.026 kg d⁻¹ for Angus, Hereford, Brahman, and Senepol, respectively).

Previous winter treatment affected ($P < 0.05$) initial BW in all 3 yr, with the heifers receiving the CS diet being heavier at the start of the summer grazing than the heifers receiving only SBM (Table 2). Breed affected initial BW in 1991 ($P < 0.05$) when Angus (253 ± 4.3 kg) had initially lighter BW than any of the other breeds (267 ± 4.4 , 269 ± 4.2 , and 272 ± 5.3 kg, respectively, for Hereford, Brahman, and Senepol).

In 2 of the 3 yr, there was a carryover effect ($P <$

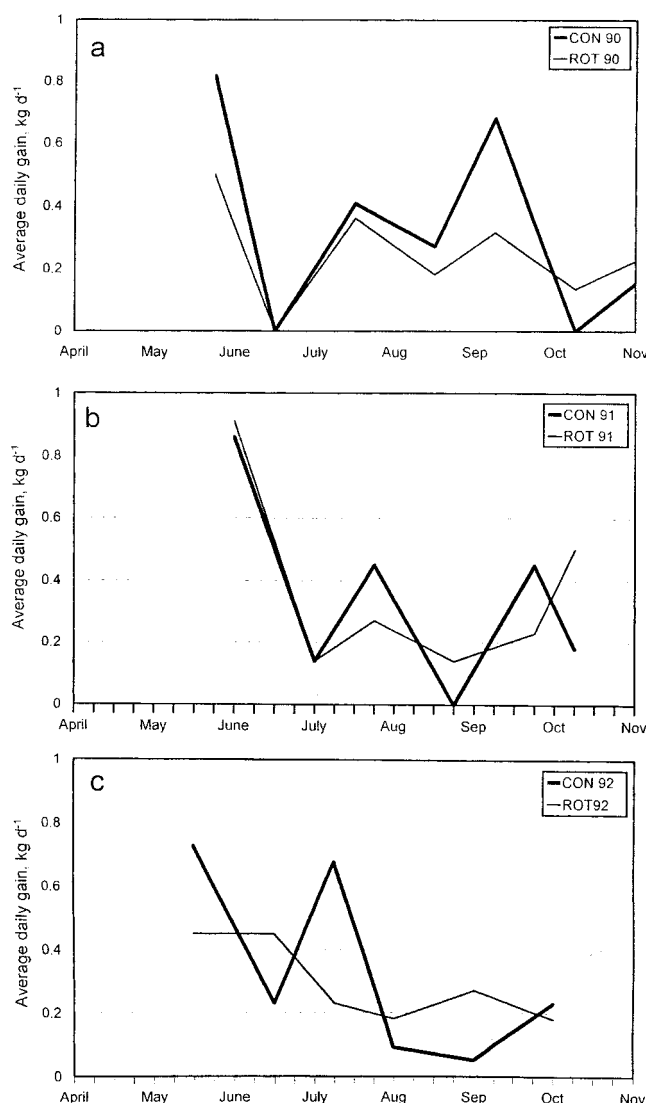


Fig. 6. Average daily gain (ADG) of heifers continuously (CON) or rotationally (ROT) grazing bahiagrass pastures in (a) 1990, (b) 1991, and (c) 1992.

0.002) of winter treatment on final BW (Table 2) but only a trend ($P = 0.07$) for summer grazing treatment to affect final BW in 1990 (337 ± 4.8 vs. 324 ± 4.9 kg for continuous and rotational grazing, respectively). There were summer treatment \times winter treatment interactions ($P = 0.03$) in 1992 when the rotationally grazed heifers that had been wintered on the CS diet gained more than any other winter treatment–summer treatment combination (340 ± 11.1 , 329 ± 10.9 , 366 ± 11.5 , and 323 ± 11.1 kg for continuous CS, continuous SBM, rotational CS, and rotational SBM, respectively). Breed affected ($P < 0.01$) final BW all 3 yr (Table 2), and the general pattern was for Angus \leq Hereford \leq Brahman and Senepol. There was a summer treatment \times breed interaction (1991, $P = 0.03$) and a summer treatment \times winter treatment \times breed interaction (1992, $P = 0.05$) in only 1 out of 3 yr.

There were numerous interactions ($P < 0.05$) between summer treatment, winter treatment, breed, and sampling date for BCS over the 3 yr, but no consistent

Table 2. Least square means \pm standard error for initial and final body weight (BW) of Angus, Hereford, Brahman, and Senepol heifers previously wintered on corn + soybean meal (CS) or soybean meal (SBM) before either continuously or rotationally grazing bahiagrass pasture in 1990 to 1992.

	Angus	Hereford	Brahman	Senepol	Mean
	kg				
1990 Initial BW					
Continuous					
CS [†]	293 \pm 10.8	287 \pm 14.7	292 \pm 11.4	280 \pm 14.7	288 \pm 6.5
SBM [‡]	261 \pm 12.2	266 \pm 19.7	265 \pm 11.1	276 \pm 12.5	267 \pm 7.1
Rotational					
CS	283 \pm 11.4	279 \pm 19.3	294 \pm 10.7	267 \pm 11.8	281 \pm 6.9
SBM	261 \pm 10.3	266 \pm 19.3	263 \pm 10.7	267 \pm 13.5	264 \pm 7.0
1990 Final BW					
Continuous					
CS	344 \pm 10.8	335 \pm 14.8	359 \pm 11.4	339 \pm 15.3	344 \pm 6.6
SBM	321 \pm 12.2	327 \pm 19.8	350 \pm 10.7	327 \pm 11.9	331 \pm 7.0
Rotational					
CS	327 \pm 11.4	327 \pm 19.4	352 \pm 10.7	304 \pm 11.9	327 \pm 6.9
SBM	313 \pm 10.4	314 \pm 19.4	344 \pm 10.7	314 \pm 13.5	321 \pm 7.0
1991 Initial BW					
Continuous					
CS	258 \pm 8.8	281 \pm 8.8	289 \pm 8.4	276 \pm 11.3	276 \pm 4.7
SBM	226 \pm 8.3	245 \pm 8.8	252 \pm 8.3	269 \pm 10.1	248 \pm 4.5
Rotational					
CS	283 \pm 8.3	281 \pm 8.3	273 \pm 8.3	288 \pm 9.5	281 \pm 4.3
SBM	244 \pm 8.8	261 \pm 9.5	264 \pm 8.3	254 \pm 11.3	255 \pm 4.8
1991 Final BW					
Continuous					
CS	289 \pm 8.3	319 \pm 11.3	356 \pm 8.3	355 \pm 12.3	329 \pm 5.1
SBM	278 \pm 8.3	309 \pm 10.7	330 \pm 8.3	343 \pm 11.3	315 \pm 4.8
Rotational					
CS	322 \pm 8.3	327 \pm 8.3	335 \pm 8.3	337 \pm 10.7	331 \pm 4.5
SBM	287 \pm 8.3	308 \pm 10.7	324 \pm 8.3	320 \pm 14.2	310 \pm 5.3
1992 Initial BW					
Continuous					
CS	293 \pm 9.2	282 \pm 15.2	273 \pm 15.2	299 \pm 18.6	287 \pm 7.5
SBM	269 \pm 9.6	275 \pm 18.6	253 \pm 13.9	282 \pm 13.9	270 \pm 7.2
Rotational					
CS	279 \pm 9.2	309 \pm 21.5	322 \pm 18.6	299 \pm 13.9	303 \pm 8.2
SBM	261 \pm 9.2	269 \pm 13.9	253 \pm 18.6	269 \pm 17.5	263 \pm 7.6
1992 Final BW					
Continuous					
CS	334 \pm 12.8	329 \pm 26.0	335 \pm 21.2	365 \pm 26.0	341 \pm 11.1
SBM	305 \pm 13.4	336 \pm 30.0	325 \pm 19.3	348 \pm 21.2	329 \pm 10.9
Rotational					
CS	323 \pm 12.8	378 \pm 30.0	397 \pm 26.0	365 \pm 19.4	366 \pm 11.5
SBM	305 \pm 12.8	331 \pm 21.2	309 \pm 26.0	344 \pm 26.0	322 \pm 11.1

[†] 2.27 kg d⁻¹ 75% cracked corn – 25% SBM mix.[‡] 0.91 kg d⁻¹ SBM.

trends for BCS were evident among any of these interactions. Heifers that had received the CS supplement averaged higher BCS ($P < 0.001$) than heifers from the SBM treatment (3-yr average of 7.8 ± 0.11 vs. 7.0 ± 0.11 for CS vs. SBM, respectively) at the start of the grazing season. Average BCS for the summer period during the 3 yr of the study also differed ($P < 0.03$) in 2 of the 3 yr due to grazing treatment, but this difference was not consistent between years (7.4 ± 0.11 vs. 7.3 ± 0.11 in 1990 and 7.6 ± 0.13 vs. 7.8 ± 0.14 in 1992 for continuous vs. rotational grazing, respectively). There was summer treatment \times winter treatment interaction ($P < 0.003$) in 1991 and 1992 because rotationally grazed heifers from the CS winter treatment had 0.3 to 0.5 higher BCS than continuously grazed heifers from the CS winter treatment (7.7 ± 0.11 vs. 7.4 ± 0.12 in 1991 and 8.5 ± 0.21 vs. 8.0 ± 0.19 in 1992, respectively). The reason for this interaction is unclear, but because the magnitude of the difference was small for the BCS rating system used, it was probably not biologically important. There was no summer treatment \times winter treatment interaction in 1990. Breed affected BCS ($P < 0.001$), with the

general ranking for the 3 yr being Angus, Hereford, Brahman, and Senepol (3-yr average of 7.6 ± 0.11 , 7.5 ± 0.18 , 7.4 ± 0.14 , and 7.1 ± 0.16 , respectively).

DISCUSSION

Although the stocking rate differed slightly across the years (0.3 head ha^{-1}), this difference was not large enough to account for a 50 to 100% difference in forage mass between 1990 and 1991 or 1992. Rainfall amount and distribution, particularly in the spring, greatly affects plant growth and limits stocking rates in peninsular Florida where the soils have very limited water-holding capacity. In 1990, lower rainfall amounts (Fig. 1) in March and April and less favorable distribution during the summer months (June, July, and August) limited forage growth that year. Forage mass averaged approximately 1000 kg ha^{-1} for the 1990 grazing season, and it was low enough ($< 500 \text{ kg ha}^{-1}$) during the spring, particularly the month of May, to limit intake, animal selectivity, or both (Marten, 1988). Heifers did not gain BW during this period in 1990 in either treatment (Fig.

6a). This may be reflected in the season-long ADG of 0.28 kg d^{-1} for that year although the seasonal ADG for 1991 was similar (0.30 kg d^{-1}) when forage mass was 50% higher. Maximum summer ADG for the 3 yr of the study was 0.36 kg d^{-1} in 1992, which was the year with the highest average standing forage mass (2000 kg ha^{-1}). Higher ADG in 1992 was partly due to greater forage mass at the start of the grazing season as a result of a later start (mid-May instead of mid-April in previous years). These ADGs are similar or slightly lower than those previously reported for bahiagrass (Sollenberger et al., 1988; Williams et al., 1991), probably reflecting differences in class of animal (i.e., heifers vs. implanted steers in most other studies) rather than differences in forage quality or quantity.

Whole-plant CP and IVOMD in our study was similar to that previously reported for continuously grazed bahiagrass (Sollenberger et al., 1988; Williams et al., 1991; Williams and Hammond, 1999). Both of these nutritional factors are highest in the spring, and in most years, both decline as the grazing season progresses; however, CP generally declines more rapidly than IVOMD with the onset of summer rains (Sollenberger et al., 1988; Williams et al. 1991; Williams and Hammond, 1999) and accelerating growth rate of the grass (Williams, 1994). This was readily evident in the decline in CP (Fig. 3) and IVOMD (Fig. 4) levels of the forage, particularly in 1991 and 1992 (Fig. 3). Environmental factors can influence the rate of this decline and, to some degree, how low CP and IVOMD levels will go (Minson, 1990). However, with tropical grasses, conditions such as cool temperatures or drought that moderately restrict growth can result in improved nutritive value (Minson, 1990). Similar to what occurs most years, CP and IVOMD declined from the start of the grazing season in 1990, but both rebounded that year and whole-plant CP remained around the 9 to 10% level through July while IVOMD was approximately $\geq 50\%$ all summer.

Simpson et al. (1998) indicated that the levels of winter supplementation used in this study, although relatively low for developing heifers when the objective is to have them calve at 2 yr of age, are typical for Florida conditions when calving at 3 yr of age is a common production practice. Because only modest differences in weight gain were observed with the different levels of winter supplementation, it was economically important to learn that initial BW and BCS advantages resulting from CS supplementation generally were maintained during the summer grazing phase regardless of grazing management. Heifers fed on the CS winter supplement conceived at an earlier age than those fed SBM (Chase et al., 1997). Within the breeds studied, summer ADG was highest for Brahman heifers, possibly reflecting their tolerance to higher summer temperatures, which can impact total intake, and their being less physiologically mature than the temperate breeds.

In growth and reproduction studies involving beef cattle, various blood parameters are measured to determine physiological changes that might be occurring as a result of treatments. Plasma glucose has been corre-

lated to changes in ovarian activity in cattle (Rutter and Manns, 1987; Rutter and Manns, 1988), and Simpson et al. (1998) found that a subset of heifers used in this study receiving CS had higher levels of PGLU and were younger at first conception than a similar subset of heifers receiving only SBM. Regardless of summer grazing management, we found that unlike changes in BW, there was no carryover effect of winter treatment on PGLU levels. This was not surprising because there was only a trend in one year for ADG to differ as result of summer grazing treatment. Across dates in this study, PGLU levels were, in general, highest in the spring when forage nutritional value was highest. Breed differences were found for PGLU, but unlike the consistent pattern of higher PUN for tropically vs. temperately adapted cattle types, no consistent pattern has been observed for PGLU (Chase et al., 1993; Simpson et al., 1994).

Concentration of PUN reflects the protein to energy balance in diets of ruminants and can be used to monitor the nutritional status of grazing cattle (Hammond et al., 1994). On tropical grass pastures, Hammond et al. (1993) found more positive responses in yearling cattle or stockers to protein supplementation when PUN levels fell below 9 mg dL^{-1} . In this study, PUN levels found during most of the grazing season were $< 9 \text{ mg dL}^{-1}$, which suggests that overall animal performance would have been improved with late-summer protein supplementation. As previously noted (Chase et al., 1993; Simpson et al., 1994), tropically adapted breeds, Senepol and Brahman, maintained higher average PUN values throughout the grazing season than the temperately adapted breeds, Angus and Hereford.

In all 3 yr, the PUN concentrations in continuously grazed heifers were on average higher than those in the rotationally grazed heifers, but only in 1990, when PUN levels were $> 9 \text{ mg dL}^{-1}$ into July and IVOMD remained adequate, did this result in the trend for higher ADG and final BW. Studies in Australia with tropical forage species have shown declines in animal performance during the wet season when stocking rates effectively decline due to increased rate of grass growth (Stobbs, 1970; Edye et al., 1978). This decline in animal performance, when selectivity should have been enhanced, has been explained, in part, by the inability of animals to maintain the quality and quantity of forage in even the heavily spot-grazed areas in pastures (Edye et al., 1978). These studies were conducted with taller-growing tropical bunchgrass species, and it was speculated that this might not be such a problem with shorter-growing grass species (Edye et al., 1978). Our results suggest that for bahiagrass, heifers may be unable to utilize the forage quickly enough to maintain forage nutritive value at levels that would maintain higher rates of animal performance. When bahiagrass growth was restricted, as occurred in 1990, continuous grazing allowed the cattle to maintain a higher quality diet, which resulted in improved performance compared with rotational grazing. One possible method of creating periods of restricted grass growth would be to make seasonal adjustments in stocking density on tropical species to better match rate of forage growth with maximum animal performance

(Roquette, 1988; Williams and Hammond, 1999). More information is needed concerning the interaction of seasonal changes in stocking density with forage nutritive value and animal performance in the subtropical USA.

CONCLUSION

Because summer grazing treatments did not affect heifer performance in most years, the major effects on heifer performance noted in this study resulted from (i) the general effects of change in forage nutritive value during the grazing season; (ii) the carryover effect of previous winter supplementation; and (iii) breed differences, particularly temperate vs. tropical breeds. It was economically important to learn that initial BW and BCS advantages resulting from CS supplementation generally were maintained during the summer grazing phase regardless of grazing management.

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